REMARKS

By the foregoing preliminary amendment, claims 1-4 have been amended, claims 5-8 have been canceled and new claims 9-16 have been presented. No new matter has been added. Applicants assert that the present invention is new, non-obvious and useful. Prompt consideration and allowance of the pending claims is respectfully requested.

Respectfully submitted,

Gary M. Butter
PTO Reg. No. 33,841
Attorney for Applicant
(212) 408-2546

PATENT

~~DESCRIPTION~~BAKER BOTTS L.L.P.

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NEW YORK, NEW YORK 10112

TO ALL WHOM IT MAY CONCERN:

Be it known that WE, MASAFUMI MIYAZAKI, SHUICHI INOUE, TOSHIKAZU NISHIMURA and HIROSHIGE INOUE, citizens of Japan, whose post office addresses are c/o Nippon Steel Corporation, Technical Development Bureau, 20-1, Shintomi, Futtsu-shi, Chiba 293-8511, Japan, have invented an improvement in

~~PRODUCTION METHOD~~METHODS OF AUSTENITIC STAINLESS STEEL THIN STRIP CASTING

of which the following is a

SPECIFICATION

~~Technical Field~~

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application is a national stage application of PCT Application No. PCT/JP03/03891, which was filed on March 27, 2003 and published on October 2, 2003 as International Publication No. WO 03/080273 (the "International Application"). This application claims priority from the International Application pursuant to 35 U.S.C. § 365. The present application also claims priority under 35 U.S.C. § 119 from Japanese Patent Application No. 2001-335895, filed on March 27, 2003, the entire disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to ~~a method~~methods for casting an austenitic stainless steel thin strip casting through a continuous caster ~~wherein mold walls move synchronously with the casting, the caster being represented by a twin-drum type caster, and a casting obtained by the method~~. In particular, casting an austenitic stainless steel thin strip casting through a continuous caster, e.g., a twin-drum type caster, in which the mold walls move synchronous with the casting to obtain a casting, wherein defects on a steel sheet formed after cold rolling or cold forming are prevented.

~~Background Art~~

BACKGROUND

[0003] Synchronous continuous casting processes are processes that do not have a relative speed difference between a casting and the inner walls of a mold. For example, such as a twin-drum process (a twin-roll process), a twin-belt process, a single-roll process and the like~~, as described in the papers published in the special edition of "Tetsu to Hagane," A197-A256, 1985, for example~~. A twin-drum type ~~continuous casting process, as a~~ synchronous continuous casting process~~,~~ is a continuous casting process that consists of the steps of: (i) pouring molten steel into a continuous casting mold composed of a pair of cooling drums ~~having an~~, which may have identical ~~diameter~~diameters or different diameters and ~~being~~may be disposed in parallel ~~with~~

~~each other~~ or with an inclination relative to each other, and side weirs for sealing both ~~the~~ end faces of the cooling drums; (ii) forming a solidified shell on the circumference of each of the cooling drums; and (iii) uniting the solidified shells ~~into one in the vicinity of~~near a position where ~~both~~ the rotating cooling drums come closest to each other (the so-called "kissing point~~"); and thus forming~~) to form a united thin strip casting.

[0004] It is known that surface defects (e.g., unevenly glossy defects ~~when they are generated~~ on the surface of a cold-rolled product and rough surface defects ~~when they are generated~~ on the surface of a formed product) are sometimes generated along the rolling direction ~~on~~of a product~~,~~. For example, surface defects may be formed when the product ~~being~~is produced by cold rolling, with hot rolling not applied beforehand, ~~a~~and thin strip casting ~~cast~~ through a twin-drum type continuous casting process or the like, when cold forming (e.g., draw forming or stretch forming~~, in particular~~) is applied thereto. ~~Those~~These surface defects are generated~~,~~ in a different manner from ~~an already known~~ the "orange peel phenomenon ~~that appears depending~~," which depends on the diameter of the crystal grains of a cold-rolled product, individually or compositely. In particular, the defects may be in the forms of: (1) small undulated surface defects not more than several millimeters in length and not more than 0.5 mm in width on average; and (2) large stream patterned surface defects not more than several hundred millimeters in length and not more than 3 mm in width on average. ~~In particular, those~~For example, these surface defects

~~are apt to~~may be observed when a BA product (a product produced through bright annealing) is subjected to stretch forming and ~~they~~may deteriorate the appearance of the formed product~~ in some cases~~.

[0005] ~~(1)~~ The small undulated surface defects, of not more than several millimeters in length and not more than 0.5 mm in width~~ are the ones that are~~, may be generated~~,~~ in~~ a kind of~~ steel ~~wherein~~where δ-ferrite remains in an austenite phase~~,~~. These surface defects may be caused by the ~~unevenness of a structure~~uneven structures formed on ~~both~~ the surfaces of a casting as a result of the variation of the residual amount of δ-ferrite ~~caused by the variation of~~due to the heat history of the casting. ~~In this case~~Thus, the positions where the surface defects are generated on ~~both~~ the top and bottom surfaces of a steel sheet ~~where surface defects are generated~~ are not identical with each other. Japanese ~~Examined~~ Patent Publication No. H5-~~23861 proposes a technology~~23861, the entire disclosure of which is incorporated herein by reference, discloses a method of preventing surface defects on a steel sheet product by adjusting the interval of dimples on the surfaces of the cooling drums. Additionally,~~ and~~ Japanese ~~Unexamined~~ Patent Publication No. H5-~~293601 proposes a technology~~293601, the entire disclosure of which is incorporated herein by reference, discloses a method of eliminating δ-ferrite on the surface layers of a casting by delaying the cooling of the casting ~~coming~~after it

comes out ~~from a mold in~~of a high temperature ~~range~~mold. Further, Japanese ~~Unexamined~~ Patent Publication No. 2000-219919 the entire disclosure of which is incorporated herein by reference, discloses a method comprising the steps of: (i) casting a thin strip casting; ~~thereafter~~(ii) imposing a strain to the vicinity of the surfaces of the casting through shot blasting; and ~~subsequently applying annealing. In this case, it is said that, as annealing is applied after imposing a strain on the surfaces of a casting, the recrystallization at the surfaces advances, the size of the recrystallized crystal grains is uniformized, and that this effectively acts on the uniformization of~~(iii) annealing. Thus, recrystallization of the strained surface during annealing creates uniformly sized crystal grains and therefore removes the surface gloss.

[0006] ~~(2)~~ The large stream patterned surface defects, not more than several hundred millimeters in length and not more than 3 mm in width, are ~~the ones that are generated~~ caused by the local variation of deformation resistance ~~that appears as a result of the~~due to uneven distribution of Ni segregation (e.g., normal segregation and inverse segregation) remaining at the finally solidified portion of a casting, ~~namely~~e.g., at ~~the~~a portion in the middle of the thickness of a steel sheet product. ~~The feature of this case is that~~These surface defects are generated at identical positions on both the top and bottom surfaces of a steel sheet. Japanese ~~Unexamined~~ Patent Publication No. H7-~~268556~~

~~discloses an invention wherein strong~~268556, the entire disclosure of which is incorporated herein by reference, discloses that Ni segregation is mitigated by performing casting while ~~a~~the degree of superheat ΔT of molten steel is controlled to not higher than 50°C during continuous casting and ~~by~~ thus ~~making~~minimizing the flow of the molten steel at the finally solidified portion ~~hardly occur~~.

[0007] ~~According to~~ Japanese Patent No. 2851252, the entire disclosure of which is incorporated herein by reference, discloses that Ni segregation ~~that causes the aforementioned large stream patterned surface defects~~ is caused by ~~the fact that~~ semisolidified molten steel ~~that~~, which is in ~~the~~a state close to ~~the~~ final solidification and has a solid phase ratio of less than ~~1.0~~about 1.0, is moved in the direction of the sheet width or in the direction of casting by a driving force. ~~The~~This driving force ~~for the movement of molten steel~~ is created by the pressing force P of a mold, imposed when a casting is formed by sticking the solidified shells together on the mold wall faces ~~together~~. ~~Then~~Consequently, Ni segregation ~~caused by the movement of molten steel is~~may be mitigated and ~~the~~therefore reduce surface defects ~~are reduced~~ by defining ~~a~~the pressing force P ~~on the basis of the~~as a function of a degree of superheat ΔT of molten steel and controlling the pressing force P to roughly not more

than 5 t/m, ~~concretely~~and more particularly to controlling the pressing force P to about 2.5 t/m.

[0008]

[0009] ~~Problem to be Solved by the Invention~~

[0010] By the various corrective measures ~~mentioned~~described above, the surface defects generated when a product produced by cold-rolling a thin strip casting is ~~further~~ subjected to cold forming have been significantly improved. ~~Meanwhile~~However, it has been found that previously unknown minute surface defects~~, that are different surface defects from hitherto known ones, are~~ may be generated. ~~The newly found~~These new surface defects are sometimes recognized as unevenly glossy defects at the stage of a cold-rolled steel sheet in the same way as before, but are far finer and smaller than the ~~hitherto~~previously known ~~ones~~defects. Further, when ~~the newly found surface~~these new defects are very ~~much smaller, though~~small they are not recognized as unevenly glossy defects at the stage of a cold-rolled steel sheet or after usual cold forming~~, they~~ but are found as minute rough surface defects after excessive cold forming ~~such as~~is applied, e.g., deep drawing or stretch forming ~~is applied and they~~, which may cause ~~a problem in some cases. In any case, the newly found surface defects, though they are smaller than hitherto known surface defects, also have to be eliminated in an application of a~~problems

in some applications. Therefore, these defects must be eliminated in cold-rolled steel sheet~~, for example, in an application wherein~~ applications, e.g., where buffing after forming is omitted.

[0011] ~~The~~As described above, the conventional large stream patterned surface defects~~, not more than several hundred millimeters in length and not more than 3 mm in width,~~ are generated at identical positions on both the top and bottom surfaces of a steel sheet~~, the~~. The protrusions and depressions thereof are distributed in the form of streaks or lines~~, and the~~ with a height difference between a protrusion and a depression ~~is~~of about 1 to 3 μm. ~~An~~A Ni segregation portion is located ~~at a portion~~ where ~~a~~the conventional large stream patterned surface defect is generated~~ and~~, with normal segregation and inverse segregation ~~exist~~existing in the form of bands in the middle of the sheet thickness. ~~On the other hand, in the case of~~In contrast, although the newly found surface defects~~, though they~~ are generated at identical positions on both the top and bottom surfaces of a steel sheet ~~like in the case of the conventional large stream patterned surface defects,~~ the protrusions and depressions are distributed sporadically and in a zigzag pattern in the form of spots, ~~the~~with a length ~~thereof is~~of several tens of millimeters~~,~~ and ~~the~~a height difference between ~~a protrusion and a depression is nearly in the range from~~protrusions and depressions of from

about 0.1 μm to about 1 μm. ~~Here~~Thus, ~~the~~these newly found surface defects ~~are called "~~have been named "salt-and-pepper~~ and salt~~ unevenly glossy defects"~~ as the name thereof~~ at the stage of a cold-rolled steel sheet. At a portion where a salt-and-pepper~~ and salt~~ unevenly glossy defect is generated in the middle of the sheet thickness, an Ni inverse segregation portion exists ~~individually~~ and normal segregation does not exist in the adjacent vicinity. In this respect, a salt-and-pepper~~ and salt~~ unevenly glossy defect is differentiated from a conventional rough surface defect where both normal segregation and inverse segregation coexist.

[0012]

[0013] ~~Disclosure of the Invention~~

SUMMARY OF THE INVENTION

[0014] The ~~object of the~~ present invention ~~is, in a method~~relates to methods for casting an austenitic stainless steel thin strip casting through a continuous caster~~ wherein mold walls move synchronously with the casting, to provide a production method capable of preventing pepper and salt~~. In particular, casting an austenitic stainless steel thin strip casting through a continuous caster, e.g., a twin-drum type caster, in which the mold walls move synchronous with the casting to obtain a casting, wherein defects, e.g., salt-and-pepper unevenly glossy defects—

~~distributed zigzag in the form of spots, that are seen~~, on a steel sheet formed after cold rolling or cold forming~~, from being generated~~ are prevented.

[0015] ~~The gist~~According to one embodiment of the present invention~~ is as follows: (1) A~~, a method for producing an austenitic stainless steel thin strip casting through a continuous caster, wherein mold walls move synchronously with the casting, ~~characterized in that the~~includes applying a pressing force P of ~~the~~at least one mold wall ~~faces~~face against ~~the~~a casting is more than ~~1.0 and less than 2.5 t/m. (2) A method for producing an austenitic stainless steel thin strip casting through a continuous caster wherein mold walls move synchronously with the casting, characterized in that~~ about 1.0 and less than about 2.5 t/m. In a further embodiment, the pressing force P of the at least one mold wall ~~faces~~face against the casting is more than about 1.1 and ~~not more~~less than about 1.6 t/m.

[0016] ~~(3) A~~According to another embodiment of the present invention, a method for producing an austenitic stainless steel thin strip casting~~, characterized in that:~~ through a continuous caster ~~used~~, wherein the mold walls move synchronously with the casting, the continuous caster is a twin-drum type continuous caster~~;~~, and the drum radius R (m) and the pressing force P (t/m) of at least one mold wall ~~faces satisfy~~face satisfies the relation $0.5 <= (\sqrt{R}) \times P <= 2.0$. ~~(4) A method for producing an austenitic~~

~~stainless steel thin strip casting, characterized in that: a continuous caster used is a twin drum type continuous caster; and~~ According to a further embodiment of the present invention, the drum radius R (m) and the pressing force P (t/m) of at least one mold wall ~~faces satisfy~~face satisfies the relation $0.8 \le (\sqrt{R}) \times P \le 1.2$.

[0017] ~~(5) A method for producing an austenitic stainless steel thin strip casting according to any one~~According to another embodiment of the ~~items (1) to (4), characterized in that~~present invention, the height of a molten steel pool formed between at least two mold walls is ~~not less~~more than about 200 mm and ~~not more~~less than about 450 mm.

[0018] ~~(6) A method for producing an austenitic stainless steel thin strip casting according to any one~~According to another embodiment of the ~~items (1) to (5), characterized in that~~present invention, a solidification time, defined by ~~the~~a span of time ~~from the~~between a time when at least one moving mold ~~walls contact with~~wall contacts molten steel to ~~the~~a time when ~~the~~at least two solidified shells ~~of both sides~~ unite, is ~~not shorter~~more than about 0.4 second and ~~not longer~~less than about 1.0 second.

[0019] ~~(7) A method for producing an austenitic stainless steel thin strip casting according to any one~~According to another embodiment of the ~~items (1) to (6), characterized in that~~present invention, in-line rolling is applied during the process from molding to coiling.

[0020] ~~(8) An austenitic stainless steel thin strip casting produced by a method according to any one of the items (1) to (7), characterized in that the~~According to another embodiment of the present invention, a degree of Ni inverse segregation, defined by the ratio of ~~the~~an amount of Ni at Ni inverse segregation portions to ~~the~~an average amount of Ni in ~~the~~an entire steel is in the range from about 0.90 to about 0.97.

[0021]

[0022] ~~Brief Description of the Drawings~~

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] Figure 1 is a ~~schematic~~diagram showing ~~a situation of~~ casting ~~when~~with a twin-drum type continuous caster~~ is used.~~;

[0024] Figure 2 is ~~another schematic~~a diagram showing ~~a situation of~~ casting ~~when~~with a twin-drum type continuous caster~~ is used.~~;

[0025] Figure 3 is a graph showing the relation of the degrees of Ni inverse segregation, the existence of salt-and-pepper ~~and salt~~ unevenly glossy defects, and the pore area ratios to the pressing forces of drums~~.~~;

[0026] Figure 4 is a graph showing the relation among the drum radiuses R, the pressing forces P, and the existence of salt-and-pepper ~~and salt~~ unevenly glossy defects~~.~~;

[0027] Figure 5 (a) is a perspective sectional view showing ~~a situation of~~ the formation of salt-and-pepper ~~and salt~~ unevenly glossy defects on a steel sheet after cold rolling and annealing~~, and Figure 5 (b) is a perspective sectional view showing a situation of the formation of pepper and salt unevenly glossy defects on a steel sheet after cold forming.~~; and

[0028]

[0029] ~~Best Mode for Carrying out the Invention~~

[0030] Figure 5 (b) is a perspective sectional view showing the formation of salt-and-pepper unevenly glossy defects on a steel sheet after cold-forming.

DETAILED DESCRIPTION

[0031] The mechanism of generating the conventional large stream patterned rough surface defects, not more than several hundred millimeters in length and not more than 3 mm in width, ~~is that,~~ as ~~stated~~discussed above, may be caused by Ni segregation ~~is generated caused by the fact that~~due to the movement of semisolidified molten

steel~~that is~~, i.e., steel in ~~the~~a state close to ~~the final~~ solidification ~~and has~~with a solid phase ratio of approximately less than ~~1.0 is moved~~1.0, in the direction of the sheet width or in the direction of casting ~~by~~, which results from a driving force and ~~the generated Ni segregation~~ causes rough surface defects ~~(~~, e.g., unevenly glossy defects~~)~~. ~~The above~~This mechanism can be estimated ~~from the fact that~~since Ni normal segregation and Ni inverse segregation coexist adjacently and ~~moreover the~~there is a mass balance of ~~the~~ both ~~is secured~~.

[0032] On the other hand, in the case of salt-and-pepper ~~and salt~~ unevenly glossy defects that are the subject of the present invention, as shown in Figure 5, the size of each of the defects ~~is~~are on the order of about several tens of millimeters in length in the casting direction 20 and several millimeters in width ~~in terms of the size in the state of a casting and the~~. These defects are generated separately from each other~~,~~ and distributed sporadically, randomly and ~~zigzag~~zigzagged in ~~the~~an area of about several hundreds of millimeters in the casting direction and several tens of millimeters in the width direction at each portion of a casting 5. The unevenly glossy defects 13 are generated at identical portions on both the top and bottom surfaces of a casting and ~~an~~a Ni inverse segregation portion 12 exists at the portion ~~corresponding to the portion~~ where an unevenly glossy defect is generated in ~~an equiaxed~~a crystal portion 11 that is located at the middle portion of the sheet thickness. The degree of Ni inverse segregation (the ratio of the amount of Ni at Ni inverse segregation

portions to the average amount of Ni in ~~an entire~~the steel) is roughly not more than about 0.9. When annealing is applied after cold rolling, as shown Figure 5 (a), a phenomenon is observed wherein the sheet thickness at a portion where an unevenly glossy defect 13 is generated is thinner ~~than that at the other~~by about 0.1 μm as compared to the adjacent portions ~~by about 0.1 μm~~. This is because the amount of work-induced martensite, formed by cold rolling at an Ni inverse segregation portion ~~12~~12, is larger than ~~that~~ at the ~~other~~ adjacent portions, and thus volume shrinkage increases at ~~an~~a Ni inverse segregation portion 12 after annealing ~~becomes larger, and, as a result,~~ generating a depression ~~is generated there~~. When cold forming, such as stretch forming or draw forming, is applied on top of that, as shown in Figure 5 (b), a phenomenon is observed wherein the sheet thickness at a portion where an unevenly glossy defect 13 is generated is thicker ~~than that at the other~~by about 1 μm as compared to the adjacent portions ~~by about 1 μm~~. This is because plastic deformation is uneven during forming due to ~~such~~the unevenness of the martensite amount as stated above. As a result, a salt-and-pepper ~~and salt~~ unevenly glossy defect is generated at a portion corresponding to ~~an~~a Ni inverse segregation portion on the surface of a steel sheet after forming.

[0033] ~~As~~Since uneven plastic deformation during forming functions rather strongly ~~than~~, as compared to volume shrinkage after annealing in the aforementioned mechanism, the

height difference between a protrusion and a depression ~~in the former case becomes larger than that in the latter case~~will be larger for uneven plastic deformation. Therefore, ~~in accordance with~~depending on the degree of Ni inverse segregation, there may be a ~~case~~situation where Ni inverse segregation~~, that has been harmless in the latter case, turns to be harmful in the former case. In other words, there may be a case where~~ becomes significant after cold forming. For example, rough surface defects may appear after cold forming even though such defects are not present in a steel sheet after cold rolling and annealing~~has been in a sound state.~~. In such a situation conventional large stream patterned surface defects, not more than several hundred millimeters in length and not more than 3 mm in width, may be a problem.

[0034] ~~In such a situation that conventional large stream patterned surface defects, not more than several hundred millimeters in length and not more than 3 mm in width, have been a problem, in the event of evaluating~~ Ni segregation (normal segregation and inverse segregation) that causes surface defects~~, it has been possible to evaluate the effect of improving segregation~~ may be improved by evaluating the amount of Ni, for example, roughly in a region of 25 μm in the thickness direction and 500 μm in the width direction at a segregation portion~~. That has been~~ in the case of

conventional large stream patterned surface defects, for example, as disclosed in Japanese patent No. ~~2851252. On the other hand, in the case of pepper and salt~~2851252, the entire disclosure of which is incorporated herein by reference. However, since salt-and-pepper unevenly glossy defects~~, since they have the nature of appearing~~ appear very minutely and sporadically, it ~~is impossible to evaluate the soundness thereof by an existing method of evaluating segregation. The reason is that, whereas there has been nothing to do beyond just to evaluate segregation in a relatively small range, as the size of an Ni segregation portion has been large and Ni inverse segregation portions have distributed randomly and relatively uniformly in a cross section in the case of conventional large stream patterned surface defects, it is~~may be difficult to evaluate segregation by this method since it may be necessary to evaluate Ni amount in detail over a wider range~~than before, for example a range~~. In particular, it may be necessary to evaluate Ni segregation in a range of about several millimeters in the width direction~~, as Ni inverse segregation portions distribute minutely and sporadically~~ in the case of salt-and-pepper~~and salt~~ unevenly glossy defects~~that are the subject of the present invention~~.

[0035] On the basis of the aforementioned nature of salt-and-pepper ~~and salt~~ unevenly glossy defects, the mechanism of generating ~~an~~a Ni inverse segregation portion at the middle portion of the sheet thickness can be estimated as follows. When molten steel begins to solidify by contacting with mold walls immediately under a meniscus, as molten steel components including Ni in a liquid phase do not yet begin to concentrate, the concentration of each component in an initial solidification structure is basically in the state of inverse segregation, depending on the distribution coefficient of each component. The initial solidification structure is cooled directly by the mold walls, thus the speed of solidification is high~~,~~ and~~,~~ therefore~~,~~ a structure composed of chilled crystals is formed. When solidification proceeds, the components on ~~a~~the liquid phase side ~~at an~~of the interface between ~~a~~the solid phase and ~~a~~the liquid phase concentrate, ~~and~~whereas the ~~concentrations~~concentration of the components on the solid phase side are equal to the initial concentrations of the components in molten steel. ~~Also, the solidification structure transforms from chilled crystals to columnar crystals.~~

[0036] In addition, during solidification the structure transforms from chilled crystals to columnar crystals. It is known that such chilled crystals of Ni inverse segregation generated immediately under a meniscus, as ~~stated~~described above, tend to separate from solidified shells ~~right after the generation~~ and turn to free chilled crystals, based on ~~the~~a function of compositional supercooling at ~~an~~the interface between a solid phase and a liquid phase. The free chilled ~~crystala~~crystals are suspended in a supercooling zone, or ~~a~~ massy

zone, on the liquid phase side ~~at an~~of the interface between a solid phase and a liquid phase, and move together with solidified shells formed along the mold walls, and reach a kissing point where both the left and right solidified shells contact with each other and ~~unite together~~are united. An equiaxed crystal region (i.e., a solid and liquid coexisting region) is formed with chilled crystals acting as nuclei right above the kissing point.

[0037] When a material balance is reached between the upper part and the lower part of a kissing point, free chilled crystals of Ni inverse segregation that have reached the middle portion of a sheet thickness right above a kissing point are fed, together with equiaxed crystals, to the middle portion of the sheet thickness while accompanying solidified shells and, as a result, inverse segregation regions are formed at the middle portion of the sheet thickness uniformly in the directions of the width and length.

[0038] ~~When a material balance is secured between the upper part and the lower part of a kissing point, free chilled crystals of Ni inverse segregation that have reached the middle portion of a sheet thickness right above a kissing point are fed, together with equiaxed crystals, to the middle portion of the sheet thickness while accompanying solidified shells and, as a result, inverse segregation regions are formed at the middle portion of the sheet thickness uniformly in the directions of the width and length.~~ On the other hand, when a material balance is disturbed

between the upper part and the lower part of a kissing point and equiaxed crystal regions, wherein a solid phase and a liquid phase coexist, are not fed to the middle portion of a sheet thickness, substances containing chilled crystals of Ni inverse segregation accumulate right above the kissing point. When such accumulated substances are trapped in solidified shells ~~irregularly, for some reason,~~irregular Ni inverse segregation regions ~~are~~may be formed at the portion where the accumulated substances are trapped in the middle portion of a sheet thickness and the trapped portions ~~are~~may be differentiated from the other portions. ~~It is estimated that, as a result of the fact that the irregular trap of~~Since the substances ~~to~~trapped in the solidified shells occurs ~~at random~~randomly in the directions of the width and length of a casting, the Ni segregation portions at the middle portion of a sheet thickness ~~come to exist in the state of pepper and salt and the Ni segregation portions cause pepper and salt~~may cause salt-and-pepper unevenly glossy defects.

[0039] ~~The~~According to the present invention ~~has clarified that~~ the material balance between the upper part and the lower part of a kissing point ~~is determined depending~~may depend on the pressing force of the mold wall faces at the kissing point and, in the region of the ~~hitherto used~~ pressing force~~,~~ substances containing chilled crystals of Ni inverse segregation tend to accumulate right above the kissing point. ~~As a result, an~~Therefore, by using the appropriate ~~region of a~~ pressing force ~~exists in the~~

~~region lower than that of the hitherto used pressing force,~~ the accumulation of the substances containing chilled crystals of Ni inverse segregation ~~comes to hardly occur by performing casting with a pressing force employed in the appropriate region~~may be reduced or eliminated. As a result, Ni inverse segregation portions that ~~have existed~~exist in the salt-and-pepper~~-and-salt~~ state at the middle portion of a sheet thickness ~~do not appear any more~~are removed and the generation of salt-and-pepper~~-and-salt~~ unevenly glossy defects is eliminated.

[0040] ~~Though~~ Salt-and-pepper~~-and-salt~~ unevenly glossy defects ~~still~~may appear with a mold wall face pressing force P of 2.5 t/m~~, it is possible to reduce~~. Thus, according to one embodiment of the present invention, generation of salt-and-pepper~~-and-salt~~ unevenly glossy defects may be reduced by controlling a pressing force P to less than ~~2.5 t/m. The improvement effect increases as the pressing force decreases, and a very good result can be obtained with a pressing force of not more than 1.6 t/m. Here, a~~ about 2.5 t/m. According to another embodiment of the present invention, generation of salt-and-pepper unevenly glossy defects may be reduced by controlling a pressing force P to less than about 1.6 t/m. As used herein, the pressing force P (t/m) is a value obtained by dividing a whole pressing force (t) of a mold wall face by the mold width (m), and thus ~~means a~~is defined as the pressing

force per unit mold width. ~~A~~For example, a mold width equals a drum width in the case of a twin-drum type continuous caster.

[0041] ~~On the other hand~~However, when ~~a~~the pressing force is excessively small, center pores appear at the middle portion of the sheet thickness of a casting. ~~Though~~In particular, center pores may appear ~~with the~~when a pressing force P of 1.0 t/m~~, it is possible to cast a casting having less generation of center pores by controlling a pressing force P to more than 1.0 t/m. It is preferable that a pressing force P is more than 1.1 t/m. It is still preferable that a pressing force P is more than~~ is used. Thus, according to one embodiment of the present invention center pores may be reduced or eliminated by using a pressing force P of more than about 1.0 t/m. According to another embodiment of the present invention, center pores may be further reduced or eliminated by using a pressing force P of more than about 1.1 t/m. In yet another embodiment of the present invention, center pores may be further reduced or eliminated by using a pressing force P of more than about 1.2 t/m.

[0042] In the case where a continuous caster is a twin-drum type continuous caster, a preferable result can be obtained by specifying a pressing force P of mold wall faces in accordance with a drum radius R. ~~Concretely~~In particular, a good result ~~can~~may be obtained according to the present invention by regulating a drum radius R (m) and a pressing force P (t/m) of the mold wall faces in terms of the range of the value $(\sqrt{R}) \times P$.

[0043] As ~~explained~~discussed above, when ~~a~~the pressing force is too large, Ni inverse segregation appears at the middle portion of a sheet thickness. ~~In that situation, according as~~As a drum radius increases, the region of molten pool adjacent to a kissing point deepens with the upper part thereof narrowing and equiaxed crystals tend to accumulate with chilled crystals of Ni inverse segregation acting as nuclei~~, and therefore~~. Therefore, as the drum radius increases the upper limit in the appropriate range of a pressing force beyond which salt-and-pepper~~ and salt~~ unevenly glossy defects appear shifts toward a lower value. In contrast~~ with this, according~~, as ~~a~~the drum radius decreases, the region of molten pool adjacent to a kissing point becomes shallower with the upper part thereof widening and equiaxed crystals hardly accumulate with chilled crystals of Ni inverse segregation acting as nuclei~~, and therefore~~. Therefore, as the drum radius decreases the upper limit in the appropriate range of a pressing force beyond which salt-and-pepper~~ and salt~~ unevenly glossy defects appear shifts toward a higher value.

[0044] On the other hand, when ~~a~~the pressing force is too small, there arises a problem of abnormal casting including the generation of center pores. ~~According~~In particular, as ~~a~~the drum radius decreases, ~~a~~the molten steel pool between drums shallows~~,~~ and thus the fluctuation of a molten steel surface increases. Therefore,~~ and therefore~~ the variation of solidified shell thickness increases over the direction of the sheet width. ~~As~~ Furthermore, as the ~~variation~~variations of reactive ~~force~~forces in the direction of drum width increases, for the

above ~~reason~~reasons, the casting operation shifts toward an unstable operation ~~and~~. Therefore, as the drum radius decreases the lower limit ~~in the appropriate range~~ of a pressing force beyond which an abnormal casting occurs shifts toward a higher value. In contrast ~~with this, according~~, as ~~a~~the drum radius increases, the variation of reactive force in the direction of drum width decreases~~,~~ and the stability of casting operation improves~~, and therefore~~. Therefore, as the drum radius increases the lower limit ~~in the appropriate range~~ of a pressing force beyond which an abnormal casting occurs shifts toward a lower value.

[0045] ~~The influence of a drum radius has been explained above. In addition, the~~The present inventors intensively carried out studies by properly changing a drum radius R (m) and a pressing force P (t/m) ~~and, as a result, clarified that~~. According to the present invention the appropriate regions of a drum radius and a pressing force beyond which salt-and-pepper ~~and salt~~ unevenly glossy defects ~~occurred could~~occurs may be specified by the term $\sqrt{R} \times P$. In ~~other words, as a result of the above studies, a good result could be obtained by~~one embodiment of the present invention, a method of casting may include regulating a drum radius R (m) and a pressing force P (t/m) ~~so that they might~~to satisfy the relation $0.5 <= (\sqrt{R}) \times P <=$ ~~2.0, preferably~~2.0. In another embodiment of the present invention, a

method of casting may include regulating a drum radius R (m) and a pressing force P (t/m) to satisfy the relation $0.8 \leq (\sqrt{R}) \times P \leq$ ~~1.2, as stated above.~~1.2.

[0046] In the case of a twin-drum type continuous caster for instance, as shown in Figure 2, a molten steel pool 2 is formed on the space surrounded by a pair of drums 1 and side weirs to seal ~~the~~ both end faces of the drums. There exists ~~in the height~~a range of heights H of ~~a~~the molten steel pool 2 ~~a range appropriate for producing a casting wherein pepper and salt~~in which salt-and-pepper unevenly glossy defects are ~~handly generated. Here~~minimized. As defined herein, the height H of a molten steel pool 2 is the distance from a kissing point 4 to a molten steel surface 7 as shown in Figure 2. When ~~a~~the pool height H is ~~lower~~less than 200 mm, though the time during which chilled crystals generated at a meniscus 8 grow is short, most of the grown chilled crystals accumulate directly to a kissing point 4 and therefore salt-and-pepper~~ and salt~~ unevenly glossy defects are apt to be generated. In ~~contrast with this~~addition, when ~~a~~the pool height H ~~exceeds~~is greater than 450 mm, though most of the chilled crystals generated at a meniscus 8 disperse and remelt in a molten steel pool, some surviving chilled crystals become large since they have ~~a time~~ enough time to grow, and the amount thereof accumulated ~~to~~at a kissing point 4 increases. Therefore, salt-and~~ therefore ~~-pepper~~ and salt~~ unevenly glossy defects are apt to be generated. ~~For those reasons~~Accordingly, a good result can be obtained by regulating a

molten steel pool height H in the range from not less than about 200 mm to not more than about 450 mm.

[0047] ~~A~~The solidification time t ~~that~~ is defined as the ~~span of~~ time ~~from the time~~between when the moving mold walls contact with molten steel at a meniscus 8 to the time when solidified shells 3 of both sides unite at a kissing point ~~4 is~~4. The solidification time t may be determined by the shape of a molten steel pool 2 and the traveling speed of the mold walls. There exists in a solidification time t a range appropriate for producing a casting wherein salt-and-pepper~~ and salt~~ unevenly glossy defects are ~~little generated~~minimized. When ~~a~~the solidification time t is shorter than 0.4 second, though the time during which chilled crystals generated at a meniscus grow is short, most of the grown chilled crystals accumulate directly to a kissing point 4 and therefore salt-and-pepper~~ and salt~~ unevenly glossy defects are apt to be generated. In ~~contrast with this~~addition, when ~~a~~the solidification time t exceeds 1.0 second, though most of the chilled crystals generated at a meniscus 8 disperse and remelt in a molten steel pool, some surviving chilled crystals become large since they have a time enough to grow, the amount thereof accumulated to a kissing point 4 increases, and therefore salt-and-pepper~~ and salt~~ unevenly glossy defects are apt to be generated. ~~For those reasons~~Accordingly, a good result can be obtained by regulating a solidification time t, ~~that is~~ the ~~span of~~ time from ~~the time~~ when the moving mold walls contact with molten

steel to the time when the solidified shells of both sides unite, in the range from not shorter than about 0.4 second to not longer than about 1.0 second.

[0048] As explained above, as a pressing force P of the mold wall faces decreases, ~~and whereas~~which suppresses the generation of salt-and-pepper ~~and salt~~ unevenly glossy defects ~~is suppressed favorably~~, abnormal casting including the generation of center pores is apt to occur. ~~In~~According to the present invention, it ~~becomes~~is possible to carry out casting stably with a small pressing force by applying in-line rolling during the process from molding to coiling, and thus bonding center pores with pressure~~, and, by so doing, making the center pores harmless~~. Though the situation varies depending on the composition of steel to be cast or the ~~specification~~type of ~~a~~ caster ~~including~~and drums, as long as rolling ~~enough to bond center pores with pressure~~ is applied to a casting with enough pressure and at a sufficiently high temperature to bond the center pores, it is possible to ~~make~~eliminate the effect of the center pores ~~harmless. Concretely, generally speaking, it is preferable~~. In particular, as shown in Figure 1, it is preferable to install an in-line rolling mill 6 at a place downstream of the drums ~~1 where~~1, in which the temperature of a casting is not lower than about 1,000°C and apply rolling under the condition of reducing a thickness by not less than about 10% in terms of a sheet thickness ratio. ~~In that case, it is acceptable~~Thus, as long as the center pores can bond ~~with~~, the pressure and rolling conditions are not ~~particularly~~ restricted except

by the temperature at which rolling is applied. Center pores tend to appear when a pressing force is weak~~. In that case, though center pores remain when in line-rolling is not applied, it is possible to make center pores completely harmless if in line rolling is applied. It is made possible to cast~~ and therefore the center pores may be by applying in-line rolling. Therefore, according to one embodiment of the present invention, a casting may be cast wherein the center pores are ~~hardly generated~~minimized by regulating a pressing force to more than 1.0 t/m. ~~It is~~ In particular, according to another embodiment of the present invention, it may be preferable to regulate a pressing force to more than 1.1 t/m ~~since~~to minimize the ~~susceptibility~~generation of center ~~pore generation is suppressed under that condition. It is~~pores. In still another embodiment of the present invention, it may be preferable to regulate a pressing force to more than 1.2 t/m.

Example

[0049] A twin-drum type continuous caster as shown in Figure 1 ~~was~~may be used ~~in~~according to the present invention. The width of each of the drums 1 was 1,000 mm, the thickness of each of the castings 3 mm, and the steel grade of each of the castings AISI 304 steel (austenitic stainless steel). The radius R of each of the drums 1 was 0.6 m in ~~every case~~each example described below, except Example ~~2 mentioned below.~~2. The pool height H was 350 mm in ~~every case~~each example described below, except Example ~~3 mentioned below.~~3. The solidification time t was 0.7 second in ~~every case~~each example described

below, except Example ~~4 mentioned below.~~4. When a drum radius R, a pool height H and a solidification time t are changed from the above values, the respective values are expressed in the relevant tables of the following examples.

[0050] In-line rolling was not applied in ~~the~~ Examples 1 to 4 below, but the cases of applying and not applying in-line rolling were compared in Example 5 below. When in-line rolling was applied, the in-line rolling mill 6 shown in Figure 1 was used for the rolling. The temperature of a casting at the entry of the rolling mill was 1,220°C when in-line rolling was carried out. A reduction ratio of the in-line rolling was defined by the expression (the thickness of a casting – the thickness thereof after in-line rolling)/ the thickness of a casting x 100 in terms of percentage.

[0051] The castings that were cast were cold-rolled to the thickness of 1.0 mm and thereafter subjected to stretch forming to form the shape of a cylinder 50 mm in diameter as cold forming. In that case, two kinds of stretch forming was applied; light forming of 5 mm in stretch height and heavy forming of 30 mm in stretch height.

[0052] The degree of Ni inverse segregation was obtained by measuring an Ni amount over ~~the~~a region 100 μm in thickness direction and 1 cm in width direction at the middle portion of the thickness on the cross section in the direction of the width of a casting with an X-ray microanalyzer and calculating the ratio of Ni amount in the region to the Ni amount in a ladle (~~namely~~i.e., the ~~Ni~~ amount of Ni in molten steel).

[0053] ~~Pepper~~Salt-and-~~salt~~pepper unevenly glossy defects were ~~judged~~determined by visually observing the surfaces of the specimens at the stage of cold-rolled steel sheets and after cold forming (both light forming and heavy forming). ~~In the judgment, whereas, when~~ When salt-and-pepper~~ and salt~~ unevenly glossy defects were conspicuous~~, the judgment was done with no doubt, when pepper and salt~~ no further examination was necessary. When salt-and-pepper unevenly glossy defects were ~~insignificant and~~ questionable, minute protrusions and depressions ~~emerged~~were determined as the unevenness of polish by scrubbing the surface with abrasive paper of about #1,000 in mesh~~ and, by so doing, the judgment thereof was done easily~~. In any of the cases, spot-shaped or spindle-shaped patterns that were distributed in a zigzag were judged as salt-and-pepper~~ and salt~~ unevenly glossy defects.

[0054] The area ratio of center pores was obtained by calculating the ratio (%) of the total area of center pores in the area of one square meter on the surface of a casting on the basis of radioparency photography.

Example 1

[0055] As shown in Table 1, the pressing forces P of the drums were varied in the range from 1.0 to 2.6 t/m, and the degrees of Ni inverse segregation, the existence of salt-and-pepper~~ and salt~~ unevenly glossy defects and the center pore area ratios of the steel sheets were evaluated. The results are shown also in Figure 3. In the case of No. 2 according to the present

invention, the pressing force P was 1.1 t/m, no salt-and-pepper ~~and salt~~ unevenly glossy defects appeared, which is good and, though center pores were generated at 2.5% in terms of an area ratio, the value was a level applicable to practical use. In the cases of Nos. 7 and 8 according to the present invention, the pressing forces P were 1.8 to 2.4 t/m and, though salt-and-pepper ~~and salt~~ unevenly glossy defects appeared after subjected to heavy forming in cold forming, no salt-and-pepper ~~and salt~~ unevenly glossy defects appeared at the stage of cold-rolled steel sheets and after light forming in cold forming~~, that meant good~~. In the cases of Nos. 3 to 6 according to the present invention, the pressing forces P were in the range from 1.2 to 1.6 t/m, no salt-and-pepper ~~and salt~~ unevenly glossy defects appeared, the center pore area ratios were 0%~~, and therefore very good results were secured~~.

[0056] In case of No. 1 that was a comparative example, the pressing force P was 1.0 t/m and center pores were generated by 6.3% in terms of an area ratio. In the cases of Nos. 9 and 10 which were comparative examples, the pressing forces P were from 2.5 to 2.6 t/m and salt-and-pepper ~~and salt~~ unevenly glossy defects appeared at the stage of cold-rolled steel sheets and also after cold forming.

Example 2

[0057] As shown in Table 2, the drum radiuses R were varied in the range from 0.2 to 0.8 m and the pressing forces P were varied at 4 levels, and then the existence of salt-and-pepper ~~and salt~~ unevenly glossy defects and the relation between the center pore area ratios and the values ($\sqrt{R}$) x P of the steel sheets were evaluated. The results are shown also in Figure 4. The

curves drawn in Figure 4 are the ones that have respective identical ($\sqrt{\ }$ R) x P values; from above, ($\sqrt{\ }$ R) x P = 2.2 (the upper broken line), ($\sqrt{\ }$ R) x P = 1.2 (the upper solid line), ($\sqrt{\ }$ R) x P = 0.8 (the lower solid line) and ($\sqrt{\ }$ R) x P = 0.5 (the lower broken line).

[0058] In the cases of Nos. 12 to 21 according to the present invention, the values ($\sqrt{\ }$ R) x P were in the range from 0.8 to 2.0 and a good result was obtained in any of the cases. In the case of No. 11 according to the present invention, the value ($\sqrt{\ }$ R) x P was 0.5 and, though the center pore area ratio was 1.4%, the value was a level applicable to practical use. In the case of No. 22 that was a comparative example, the value ($\sqrt{\ }$ R) x P was 2.3 and the salt-and-pepper~~-and salt~~ unevenly glossy defects were observed at the stage of the cold-rolled steel sheet and also after cold forming.

Example 3

[0059] As shown in Table 3, the molten steel heights H were varied in the range from 190 to 460 mm, the pressing forces P of the drums were fixed to 1.5 t/m, and then the existence of salt-and-pepper~~-and salt~~ unevenly glossy defects of the steel sheets was evaluated. In the cases of Nos. 24 to 26, the molten steel heights H were in the appropriate range from 200 to 450 mm and salt-and-pepper~~-and salt~~ unevenly glossy defects were not observed. In the cases of Nos. 23 and 27, as the molten steel heights H were outside the appropriate range, the salt-and-pepper~~-and salt~~ unevenly glossy defects were observed.

Example 4

[0060] As shown in Table 4, the solidification times t were varied in the range from 0.3 to 1.1 seconds, the pressing forces P of the drums were fixed to 1.5 t/m, and then the existence of salt-and-pepper~~-and-salt~~ unevenly glossy defects of the steel sheets was evaluated. In the cases of Nos. 29 to 33, the solidification times t were in the appropriate range from 0.4 to 1.0 second and salt-and-pepper~~-and-salt~~ unevenly glossy defects were not observed. In the cases of Nos. 28 and 34, as the solidification times t were outside the appropriate range, the salt-and-pepper~~-and-salt~~ unevenly glossy defects were observed.

Example 5

[0061] As shown in Table 5, the pressing forces P of the drums were fixed to 1.1 t/m, in-line rolling was applied with the reduction ratios thereof varied or was not applied, and then the existence of salt-and-pepper~~-and-salt~~ unevenly glossy defects and the center pore area ratios of the steel sheets were evaluated. In the case of No. 35, as in-line rolling was not applied, the center pore area ratio was 2.5%. In the case of No. 36, in-line rolling was applied at the reduction ratio of 8% and the center pore area ratio was 8%. In the case of No. 37, the in-line rolling was applied at the reduction ratio of 10% and the center pore area ratio was 0%, resulting in a good result. ~~Pepper~~Salt-and-~~salt~~pepper unevenly glossy defects did not appear in any of the above cases and good results could be obtained.

Table 1

No.	Pressing force P; t/m	Degree of Ni inverse segregation	~~Pepper~~Salt-and-~~salt~~pepper unevenly glossy defect		Center pore area ratio; %	Remarks
			Cold-rolled	Cold forming		

			steel sheet	Light forming	Heavy forming		
1	1.0	0.95-0.97	Nil	Nil	Nil	6.3	Comparative example
2	1.1	0.95-0.97	Nil	Nil	Nil	2.5	Invented example
3	1.2	0.95-0.97	Nil	Nil	Nil	0	Invented example
4	1.3	0.94-0.96	Nil	Nil	Nil	0	Invented example
5	1.5	0.93-0.96	Nil	Nil	Nil	0	Invented example
6	1.6	0.92-0.95	Nil	Nil	Nil	0	Invented example
7	1.8	0.92-0.94	Nil	Nil	Present	0	Invented example
8	2.4	0.90-0.93	Nil	Nil	Present	0	Invented example
9	2.5	0.88-0.91	Present	Present	Present	0	Comparative example
10	2.6	0.87-0.90	Present	Present	Present	0	Comparative example

Table 2

No.	Pressing force P; t/m	Drum radius R; m	$\sqrt{R \cdot P}$	~~Pepper~~Salt-and-~~salt~~pepper unevenly glossy defect			Center pore area ratio; %	Remarks
				Cold-rolled steel sheet	Cold forming			
					Light forming	Heavy forming		
11	1.1	0.2	0.5	Nil	Nil	Nil	1.4	Invented example
12	1.8	0.2	0.8	Nil	Nil	Nil	0	Invented example
13	2.6	0.2	1.2	Nil	Nil	Present	0	Invented example
14	1.5	0.4	0.9	Nil	Nil	Nil	0	Invented example
15	1.8	0.4	1.1	Nil	Nil	Nil	0	Invented example
16	2.6	0.4	1.6	Nil	Nil	Present	0	Invented example
17	1.5	0.6	1.2	Nil	Nil	Nil	0	Invented example
18	1.8	0.6	1.4	Nil	Nil	Present	0	Invented example
19	2.6	0.6	2.0	Nil	Nil	Present	0	Invented example
20	1.5	0.8	1.3	Nil	Nil	Present	0	Invented

								example
21	1.8	0.8	1.6	Nil	Nil	Present	0	Invented example
22	2.6	0.8	2.3	Present	Present	Present	0	Comparative example

Table 3

No.	Pressing force P; t/m	Drum radius R; m	Molten steel height H; mm	~~Pepper~~Salt-and-~~salt~~pepper unevenly glossy defect		
				Cold-rolled steel sheet	Cold forming	
					Light forming	Heavy forming
23	1.5	0.6	190	Nil	Nil	Present
24	1.5	0.6	210	Nil	Nil	Nil
25	1.5	0.6	350	Nil	Nil	Nil
26	1.5	0.6	440	Nil	Nil	Nil
27	1.5	0.6	460	Present	Present	Present

Table 4

No.	Pressing force P; t/m	Drum radius R; m	Solidification time t; second	~~Pepper~~Salt-and-~~salt~~pepper unevenly glossy defect		
				Cold-rolled steel sheet	Cold forming	
					Light forming	Heavy forming
28	1.5	0.6	0.3	Nil	Nil	Present
29	1.5	0.6	0.4	Nil	Nil	Nil
30	1.5	0.6	0.5	Nil	Nil	Nil
31	1.5	0.6	0.7	Nil	Nil	Nil
32	1.5	0.6	0.9	Nil	Nil	Nil
33	1.5	0.6	1.0	Nil	Nil	Nil
34	1.5	0.6	1.1	Present	Present	Present

Table 5

No.	Pressing force P; t/m	Drum radius R; m	In-line reduction ratio; %	~~Pepper~~Salt-and-~~salt~~pepper unevenly glossy defect			Center pore area ratio; %
				Cold-rolled steel sheet	Cold forming		
					Light forming	Heavy forming	
35	1.1	0.6	0	Nil	Nil	Nil	2.5
36	1.1	0.6	8	Nil	Nil	Nil	1.1
37	1.1	0.6	10	Nil	Nil	Nil	0

~~Industrial Applicability~~

[0062] The present invention, in a method of casting an austenitic stainless steel thin strip casting with a continuous caster wherein mold walls move synchronously with the casting, makes it possible to prevent salt-and-pepper~~-and-salt~~ unevenly glossy defects distributed zigzag in the form of spots from appearing on a steel sheet after cold rolling and cold forming by regulating a pressing force P of mold wall faces in the appropriate range from more than about 1.0 to less than about 2.5 t/m.

Fig.1

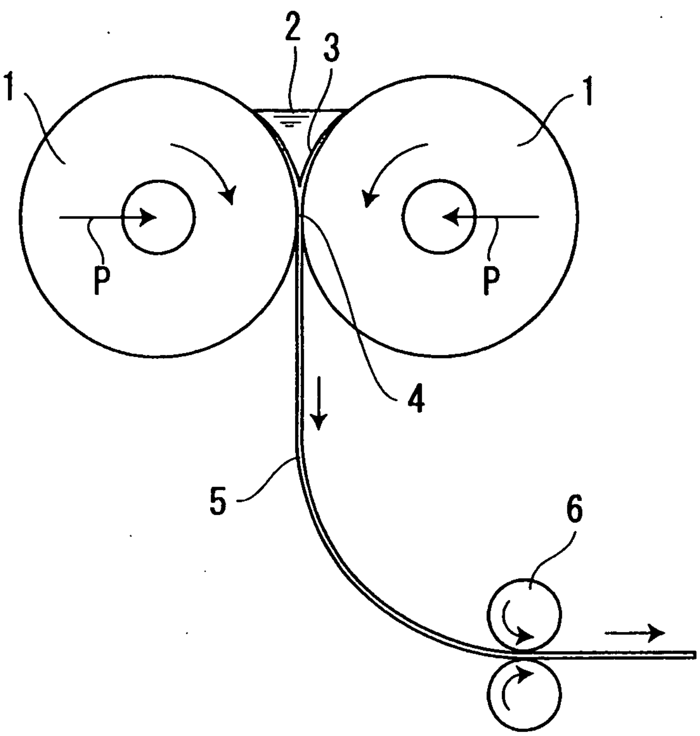


Fig.2

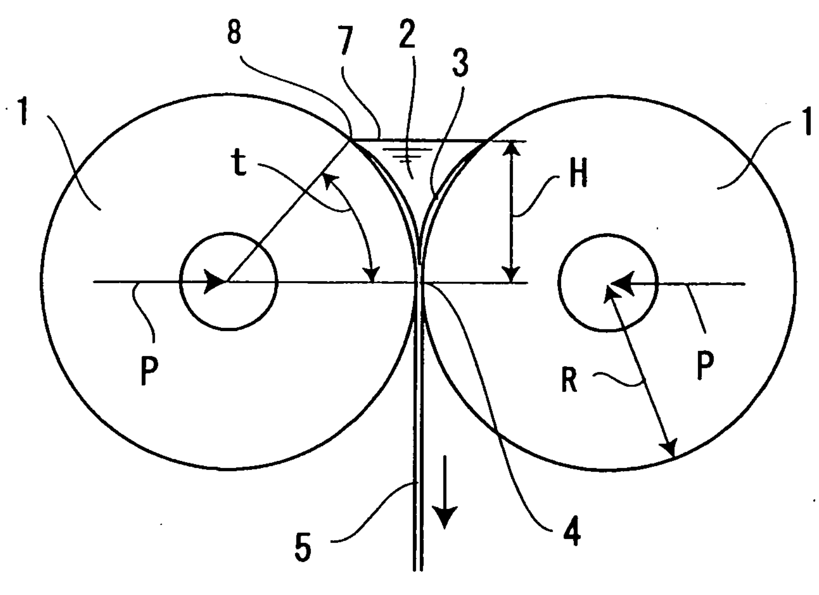


Fig.3

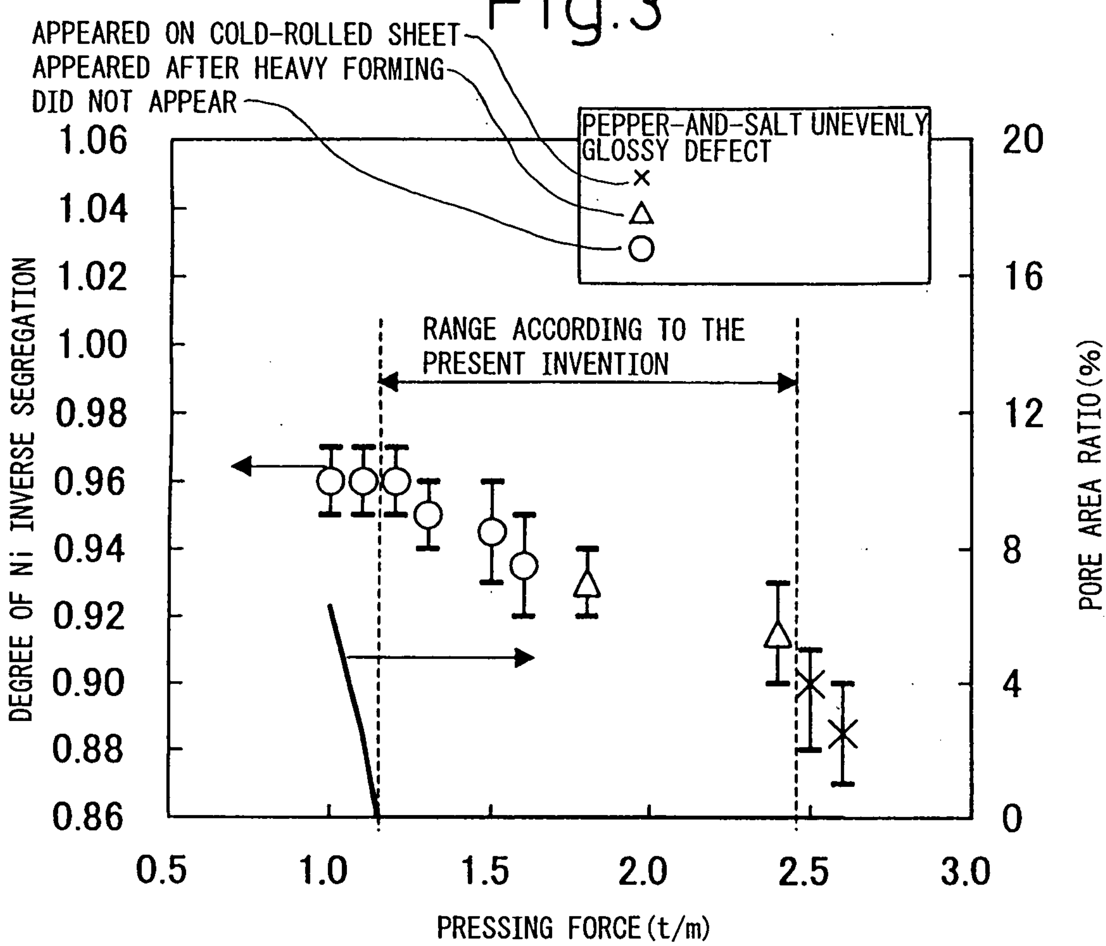
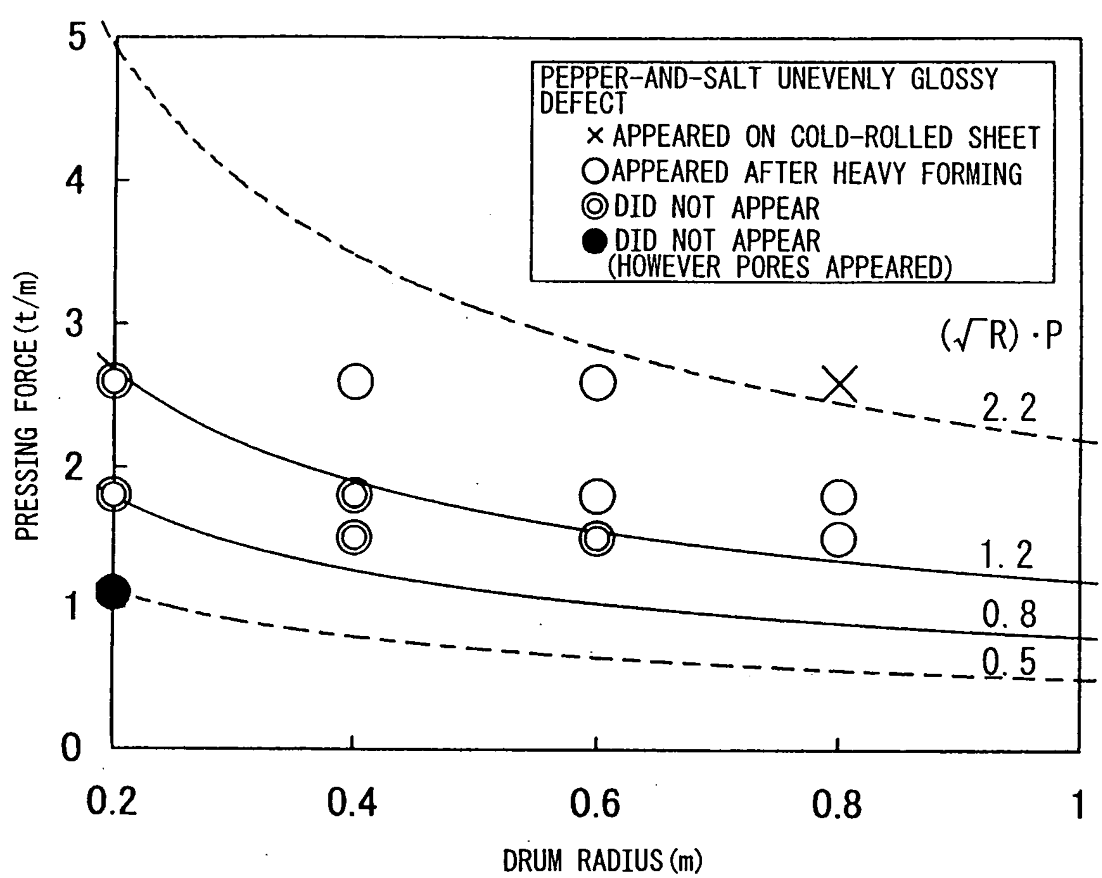

APPEARED ON COLD-ROLLED SHEET
APPEARED AFTER HEAVY FORMING
DID NOT APPEAR
PEPPER-AND-SALT UNEVENLY GLOSSY DEFECT
×
△
○
RANGE ACCORDING TO THE PRESENT INVENTION
DEGREE OF Ni INVERSE SEGREGATION
PORE AREA RATIO (%)
PRESSING FORCE (t/m)
1.06
1.04
1.02
1.00
0.98
0.96
0.94
0.92
0.90
0.88
0.86
20
16
12
8
4
0
0.5
1.0
1.5
2.0
2.5
3.0

Fig. 4



5
4
3
2
1
0
0.2
0.4
0.6
0.8
1
PRESSING FORCE (t/m)
DRUM RADIUS (m)
PEPPER-AND-SALT UNEVENLY GLOSSY DEFECT
× APPEARED ON COLD-ROLLED SHEET
○ APPEARED AFTER HEAVY FORMING
◎ DID NOT APPEAR
● DID NOT APPEAR (HOWEVER PORES APPEARED)
(√R) · P
2.2
1.2
0.8
0.5

Fig.5(a)

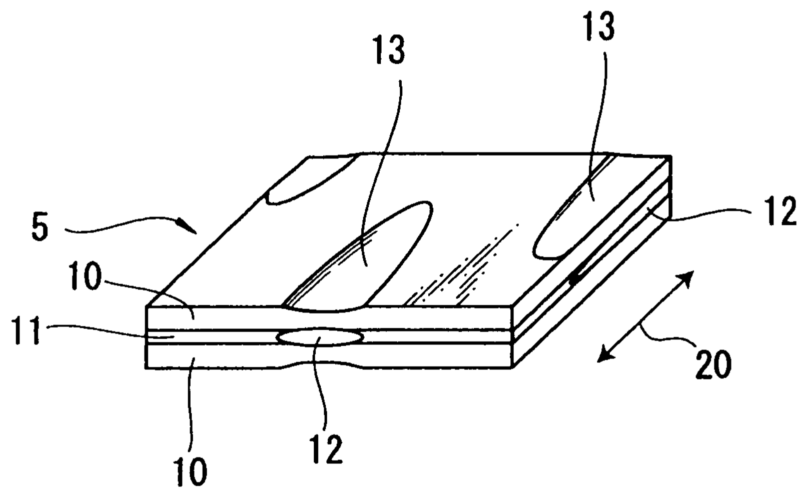


Fig.5(b)